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he said most justly, "he was a kind and generous friend to the young men and particularly solicitous for their advancement."

These were the qualities which made Dr. Dudley so successful as president of the American Chemical Society. In that high office his kindly diplomacy and great tact enabled him to harmonize many conflicting interests, and to so largely help to advance the interests of the society and bring it to that excellent condition of harmony and efficiency which now prevails.

This book will be a valuable addition to all libraries and particularly to those of the younger generation. It should be read and pondered by all men.

WILLIAM McMURTRIE

Taschenbuch für Mathematiker und Physiker.

By FELIX AUERBACH and RUDOLF ROTH. Leipzig, B. G. Teubner. 2 Jahrgang, 1911.

The second volume of the "Taschenbuch" consisting of 580 pages, may not correspond to the American idea of a "Taschenbuch," but it is an unusually convenient "Handbuch" for mathematicians and physicists. A part of the table of contents is of value only or chiefly to residents of Germany—the calendar for Berlin, the table of magnetic elements for central Europe, the "Verzeichnis der Hochschullehrer"—but with these exceptions the entire book is of general interest. The articles dealing with astronomical facts concerning planets and comets, the tables of astronomical and geodetic constants, the four-place logarithm tables of numbers and trigonometric functions, the tables of squares and Bessel functions, the numerous tables of all the important physical constants, call for no review. One notes, however, how admirable is the synopsis of the fundamental definition and operations of mathematics. A candidate for a doctor's degree in physics would do well to master the mathematical portion of this volume. Not only is here given the theoretical groundwork of the subject, there are also given labor-saving applications; *e. g.*, the complete Fourier's series are worked out for a number of common

forms of the function. There is also an application to life-insurance mathematics.

The synopsis of the fundamental principles of physics, while lacking the continuity of the mathematical synopsis, is none the less complete. There is here condensed what one ordinarily finds spread over several volumes of general physics.

The article which will be of the greatest interest to readers of the "Taschenbuch" is that on the principle of relativity by Willy Wien. It is an historical and a critical summary, complete at least in its physical aspect. The contributions to this theory made by Minkowski are briefly set forth not only in this article but also in the review of Minkowski's work with which the book opens. That one who has contributed so much to this far-reaching theory should be cut off in the very prime of his power is to be greatly deplored. Physicists and mathematicians will be pleased to have the portrait of Minkowski which accompanies the article. G. F. HULL

SPECIAL ARTICLES

CONCERNING A NEW ARRANGEMENT OF THE ELEMENTS ON A HELIX, AND THE RELATIONSHIPS WHICH MAY BE USEFULLY EXPRESSED THEREON

In this abstract of a paper which, under the title "Helix Chemica," has been published in *The American Chemical Journal*, Vol. XLV., p. 160, 1911, the writer wishes to explain briefly the grounds of the proposed arrangement and to illustrate by a few examples the many uses to which the helix may be put to bring out and compare the complex relationships of the elements.

In Fig. 1 the helix is presented from the side, in Fig. 2 from the end, where of course the front curve of each series hides those behind it. In Figs. 3-6 the curves are drawn as if they were on the end of a barrel, enabling one to see the groups and series at the same time. A great number of harmonic relations are presented on these figures, only a few of which can be discussed in this abstract. The system uses the series of Mendeléeff, but makes one half of each group the antithesis,

instead of the associate, of the other, thus separating dissimilar elements like copper and potassium.

The elements are placed in the order of their atomic weights, and with interspaces equal to the average difference of the atomic weights of adjacent elements. These differences are found to increase for the different groups of rings in the simplest arithmetical ratio 0 1 2 3 4, where, since the atomic weights are rarely whole numbers, the ratio numbers will not be exact digits, and the first term will be some very small number instead of exactly zero. The regularly recurring resemblances of the elements break them up into groups determining the number of circles of a given size and the number of interspaces and of elements upon each kind of circle; and all these relations are according to the same simplest geometrical ratio, 2 4 8 16 32. The length of each circle is obtained by combining these ratios.

Starting with the best determined circles, the lithium ring covers a range of atomic weights equal to sixteen ($H - Ne = 16$) and contains eight elements (an octant), and so the average interspace is put as two. The sodium series is wholly symmetrical with the Li ring, and so is put on a second equal coil of a spiral beside it. The third ring agrees exactly with the other two from potassium to titanium, potassium having valence and sp. gr. about like sodium and so on to titanium, which has valence and sp. gr. about 4, like silicon. Here the resemblance ceases, and vanadium, instead of agreeing with phosphorus, continues downward with valence and sp. gr. 5, and so on to the iron triad group with valence and sp. gr. equal to 8; and then the curve turns; valence and sp. gr. grow less (copper = 7, zinc = 6, etc.), until the last half of this band from Ge to Br is exactly homologous with the rearward half (in Fig. 1) of the preceding circles. Thus is established a second larger type of circle containing sixteen elements (a double octant), and making an advance in atomic weight of about 48, so that the interweight becomes about 3 and the interspace in this circle is made 3. This changes

the spiral into a helix. Four such circles can be constructed. If there are two octant circles with an interspace of 2, and four double octants with interspace 3, there should be 8 quadruple octants with interspace 4, but the curve advances only one quadrant of the first circle of this type, and does this with an interspace of 4, but becomes so complex that it falls asunder spontaneously, giving up atoms of helium whose combining weight is 4, indicating that the additions in this last curve have been by fours.

In the other direction symmetry demands a diminishing of the helix to a single half octant with interspace 1, and hydrogen stands at the beginning and helium (4) at the end of this ring. One must search among the nebulae for elements light enough to fill the two gaps, and we find among the simpler spectra in the simplest nebulae the lines 4,340 t.m. and 4,862 t.m. belonging to hydrogen, the next higher line, 4,959 t.m., belonging to nebulium, which has probably greater density than hydrogen because it is found more concentrated in the center of the nebulae, for which reasons we may assume nebulium to be a dyad and to take the second place in our circle. The next higher line, 5,007 t.m., I have tentatively assigned to the next element in this half-octant, which, from its position, must be a halogen, and which I have called proto-fluorine. The next higher number, 5,876 t.m., belongs to helium—which completes the circle.

The helix must close with the half of a quarter-octant—a single element which must have valence = 0, a density much less than hydrogen, and atomic weight much less than unity. Where would one search for such an element better than in the corona? Indeed, coronium is found to be probably lighter than hydrogen, since its lines are found further from the sun than those of hydrogen. It occupies also the position of the second element extrapolated by Mendeléeff for which he obtained the atomic weight 0.4, and suggested its identity with coronium. I have, by a similar method, obtained the value 0.3, and the symmetry of the helix would suggest that it should be still smaller.

There remains only the origin of the curve where I have placed the letter *E* for the ether, electron, protyle or Urstoff, which must have a valence and density equal to zero,¹ and we may also almost say with an atomic weight of zero, since *E* is the x of Mendeléeff for which he calculated a hypothetical atomic weight equal to one-millionth that of the hydrogen atom. The numerical relations of the helix are summarized in the following table. The positions and the number of the elements on the different circles may be obtained by drawing a regularly increasing number of diameters to each succeeding type or circle. One vertical diameter is drawn in the quarter-octant, giving place at its ends for two elements. Two diameters are drawn at right angles in the half-octant for four elements. The angles are bisected by two other diameters, giving place for eight elements in the octants; and then again bisected, giving sixteen for the double, and a final bi-

TABLE OF THE SYMMETRIES OF THE HELIX

	Quarter Octave	Half Octave	Octaves	Double Octaves	Quadruple Octaves	
1. Length of interspace (= interweights) in each type of circle. (Approximate) Unit-curve = $C_n - H$.	0	1	2	3	4	Simplest arithmetical ratio.
2. Number of interspaces in each type of circle.	2	4	8	16	32	Simplest geometrical ratio.
3. Number of elements in each type of circle.	2	4	8	16	32	
4. Number of circles of each type.	$\frac{1}{2}$	1	2	4	8	
5. Number of elements in each circle, obtained from 4 and 2.	1	4	8	16	32	Combination of above.
6. Length of each type of circle, obtained by multiplying preceding ratios in 1 and 2.	0	4	16	48	128	

¹ G. T. Stoney, "The Non-existence of Density in the Elemental Ether," *Phil. Mag.* (5), Vol. 29, p. 467.

section gives thirty-two for the quadruple octants.

The helix is placed horizontally, so that the nullivalent elements shall form its axis—they being the lightest elements—from which each group is continued downward with symmetrical increase in valence and density on either side to a maximum in the triads at the bottom. The alkalis on the one side are the antitheses of the halogens on the other, and this maximum of dissimilarity decreases downward symmetrically on either side. In the double octants it reaches a valence of 8 and a corresponding specific gravity. In the octants the circle closes with a valence of 4. It is interesting that carbon, the element of life, and silicon, the element of the rocks, form the center of the figure and are both trimorphic like the triads at the bottom of the double octants. If the helix be cut along its axis and the curves opened out on a flat surface the table of the elements given below results. This shows that the newcomers intercalated between the homologues of the preceding group are three for the octave, nine for the double-octave and seventeen for the quadruple octave if there be a triad at the bottom of the large curve. Symmetry would demand a group of twelve at that place.

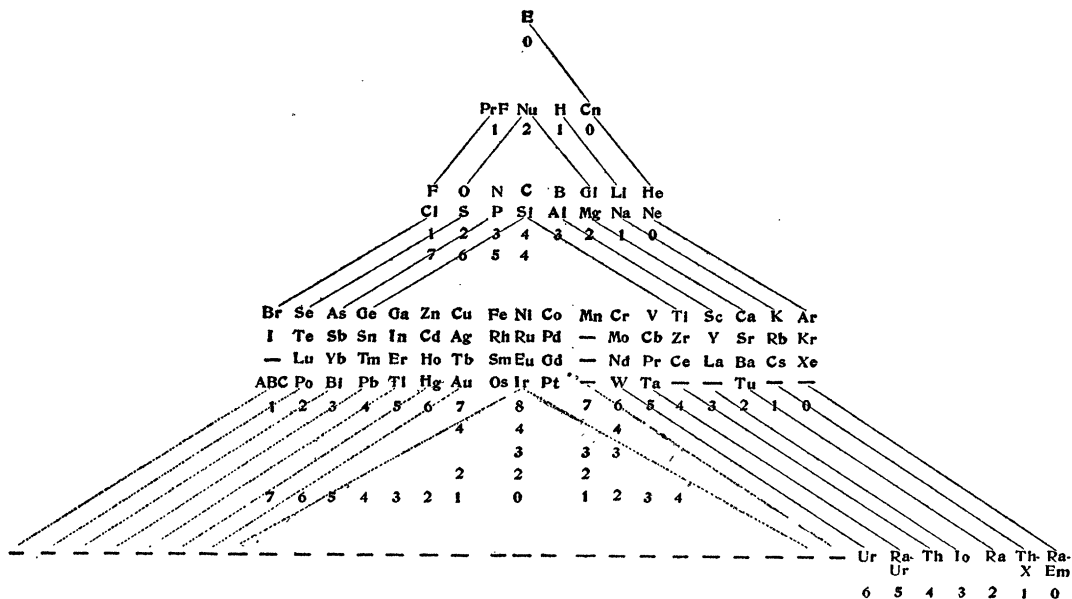
If the helix be cut along the lower line of densest elements and flattened out we have the following table, where, as the lowest elements have an equal right to be placed at either side, they are placed on both sides. This suggests the possibility that the second element beyond uranium would be the first member of a triad.

Doubtless a better suggestion would come from the preceding table, that there would be a triad or larger group at the bottom of the larger circle.

I. Longitudinal Relations. Fig. 1.

At the bottom of Fig. 1 is placed the atomic volume graph of Meyer: (1/sp. gr.) the specific volume graph of A. J. Hopkins,²

² *Jour. Am. Chem. Soc.*, July, 1911.



which puts specific volume in the place of atomic volume (at. w./sp. gr.), thus emphasizing the more important part of the atomic volume graph: the compressibility graph of T. W. Richards, changed to apply only to solids; and the graph of the fusion of the halogen compounds of Thomas Carnelley. These graphs are changed in size only to match the helix; and the exact agreement of the four large curves with the double octaves, the two small ones with the octaves, and the exact space left for the half octave is a strong confirmation of the naturalness of the helix. Further I have been able, by a very reasonable extrapolation, to prolong backward the atomic volume graph to match exactly the half and quarter octaves, and to show that its natural

culminations are in the inert gases and not in the alkalis.

The law of longitudinal condensation is especially interesting. It is only in the middle or K circle (the one containing potassium and iron) that density and valence agree from 1 in K to 8 in Fe, so that density divided by valence (D/V) equals unity. In earlier circles D/V is less than 1, so that less matter is condensed into the atom that satisfies a given amount of H, and in later circles D/V is greater than unity and more matter is condensed into the corresponding atom. Thus the densities of the iron, rubidium, samarium and platinum triads are as 8:12:16:22 + or $D/V = 1:1\frac{1}{2}:2:3$, and, if we omit gases and poorly determined elements,

																		E																		
																		Nu	PrF	Cn	H	Nu														
																		C	N	O	F	He	Li	Gl	B	C										
																		Si	P	S	Cl	Ne	Na	Mg	Al	Si										
Fe	Ni	Co	Cu	Zn	Ga	Ge	As	Se	Br	Ar	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Ni	Co																
Rh	Ru	Pd	Ag	Cd	In	Sn	Sb	Te	I	Cr	Rb	Sr	Y	Zr	Cb	Mo	—	Rh	Ru	Pd																
Sm	Eu	Gd	Tb	Ha	Er	Tm	Yb	Ln	—	Xe	Cs	Ba	La	Ce	Pr	Na	—	Sm	Eu	Gd																
Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	ABC	—	—	Tu	—	—	Ta	W	—	Os	Ir	Pt																
--	—	—	—	—	—	—	—	—	—	RaEmThX				Ru	Io	Th	Ra	Ur	—	—	—	—	—													
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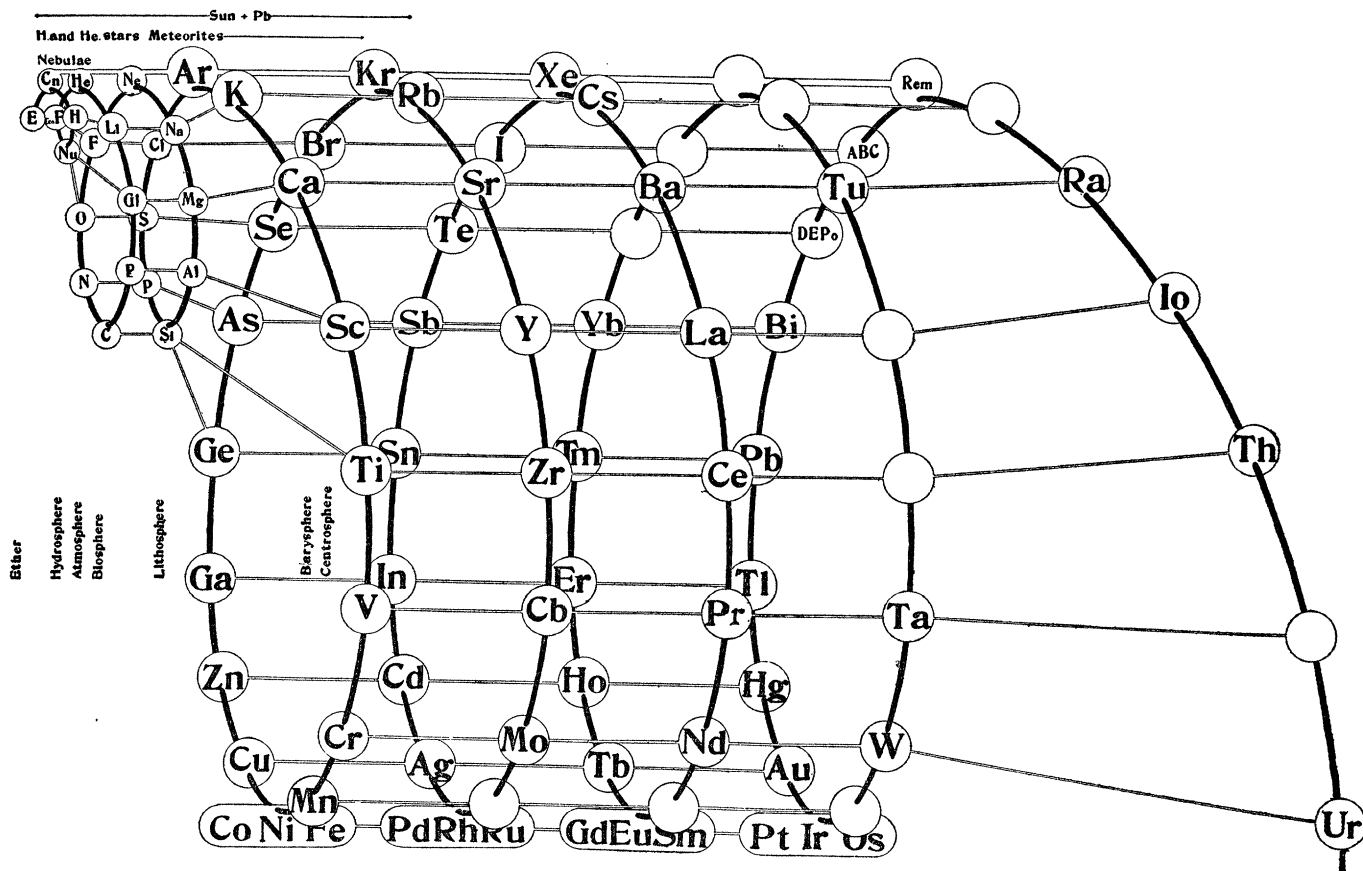


FIG. 1. A side view of the helix drawn to scale. The four graphs below have been changed, the alkalis and match closely the four double octaves, the two octaves and the half octave. The

the same ratio is true of the circles of which these triads are a part. So, omitting gases and the abnormal glucinum, we have for the carbon octave .52 and for the silicon octave .80. Thus we get, without forcing, the following average values for D/V for each of the seven circles

E	Nu	C	Si	Fe	Ru	Se	Pt
(0)	(1/3)	1/2	2/3	1	3/2	2	3.

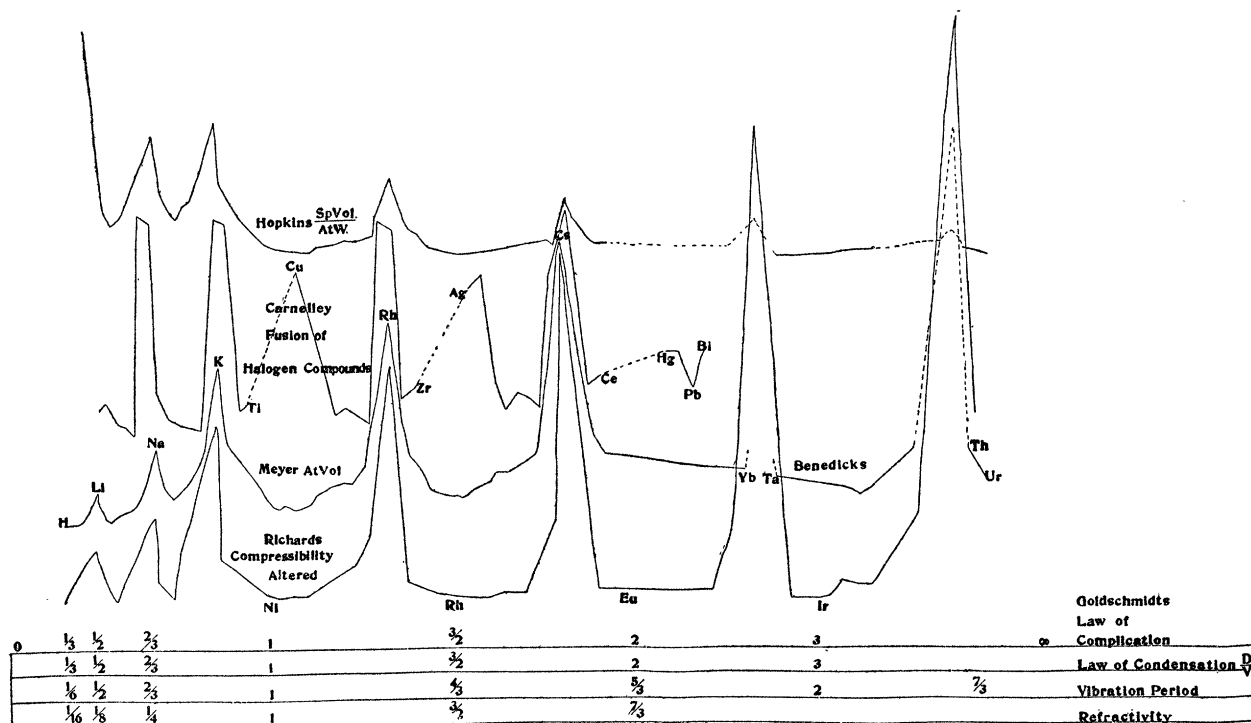
This agrees with Victor Goldschmidt's law of complication³ which shows that the law of increasing longitudinal condensation in the elements deduced above is the same as the law of the octave in music, and the fundamental law of crystallography, and the first

³ V. Goldschmidt, "Ueber Harmonie und Complication," Berlin, 1901.

two values given above are extrapolated in accordance with Goldschmidt's law.

Instead of omitting any elements as suggested above, a different and perhaps more useful line of thought may be followed. It may be assumed that the true relations would appear only when the specific gravities were taken under common conditions, say at -273° , since the elements expand unequally and sometimes diversely with change of temperature, so that we can obtain only approximate results from specific gravities taken at ordinary temperatures. We find the law most perfectly realized at the bottom of each circle at the point of greatest condensation.

Thus C as graphite is .5, Si as quartz is



in size only, to match the diagram. It will be seen that the apices of the same point exactly table showing the longitudinal octave relations is placed below.

.66, iron is 1, rhodium is 1.5, all exactly following the law. The next circle is not determined and osmium is $2.8 +$ instead of 3.

Moreover, all the elements in the lower part of each curve keep close to this average, but as we pass up the left side of the curves into the region of lessened density we come upon a sudden sharp divergence from the law in the sulphur and halogen series, caused by the polymerization or allotropic states of these elements. If we divide the numbers of the sulphur and the first half of the halogen series by two and bromium and iodine by three we obtain numbers closely coinciding with the law in every case thus:

	Fl	Cl	Br	I	S	Se	Te
Obtained by division	.55	.65	1	1.7	5	1.1	1.5
Required by the law	.5	.67	1	1.5	67	1	1.5

We may further strengthen the argument for this polymerization by the following tabu-

lation of the monovalent specific gravities or specific gravity of the elements in the carbon octant:

Li	Gt	B	C	N	O	Fl
			.3	.3		
			coal			
.58			.5		.5	
			graphite			
.9	.9		.9			1.1
			diamond			

As carbon crystallizes as graphite at normal pressures we may take that as the normal form and .5 as the normal monovalent specific gravity. There is a partially known graphitic form for boron and we may divide all the numbers in the lower row by two to get approximately the specific gravity of these elements in a form analogous to graphite. With these two changes we get averages of all the elements in each circle as follows:

ranged along a narrow rising band the sulphur and halogen series rise along different and much steeper lines and drop to the common band when divided as suggested above.

The transverse relations may be diametral or symmetrical to a vertical diameter (Fig. 3) equatorial or symmetrical to a horizontal diameter (Fig. 4), and ecliptic or symmetrical to an oblique diameter (Fig. 5).

II. *Diametral Relations. Fig. 3*

A vertical diameter representing a vertical plane bisecting the helix divides the elements into two groups, which are for many relations the counterparts of each other, some exactly and some approximately. Each of these relations is placed on a separate ring—an arrow indicating the direction of increase, and a cross the points of change. It is curious that some of these relations are symmetrical to a line a little to the right of the diameter and passing between C and Si, and others to a line passing to the left of the diameter and to the right of C and Si. The only complex relations are those of the Mendeléeff series and the magnetic relations, which would seem more simple if the two octants were drawn as a single double octant. The most inexplicable of all these relations is expressed in the outer circle. As we pass down the right-hand curves an addition of 1, 2, 3 and 4 units (= H atoms) successively produces the same unit increase in valence and density and thus there is great condensation; going up on the left with the same increasing addition and thus with still increasing mass, there is lessening valence and density, and this contrast is repeated seven times.

III. *Equatorial Relations. Fig. 4*

The horizontal diameter makes very simple relationships, most of which are combined with the diametral relations in quadrantal arrangement. The valence may be a simple diametral relation or may increase to 4 and then decrease as an equatorial relation. The electro-potential relations are equatorial in so far as they are all strong above the horizontal line

and weak below; quadrantal as far as the sign is concerned.

IV. *The Ecliptic Relations. Fig. 5*

The most important ecliptic relation is fusibility. On the one side are the high fusing elements, reaching a maximum fusing point at the end of an axis at right angles to the ecliptic. On the other side are the low fusing or volatile elements, reaching the maximum volatility at the end of the vertical axis. At one end of the ecliptic is the liquid mercury and at the other the luminous radium, while all the elements of the central most volatile quadrant, cut out of the volatile semi-circle by the equator and meridian, are absent from the sun, except these at the center, oxygen and nitrogen, the elements of the air.

Relations of Partial and Complex Symmetry. Fig. 6

The gas and rock areas show an antithesis which is only approximately an ecliptic relation. The gas area points upward and forward with the motion of the helix like a flame, and the rock area points downward and backward toward the center of the earth. The way the rocks and meteorites find orderly arrangement on this area from the light alkaline to the heavy ferric groups is very suggestive. The rock area typifies the increasing stability of the downward curves of increasing valence, density, and condensation. The gas area is its striking antithesis.

Attention may be called to the quadrilateral of life, CHON, in the center of the figure, surrounded by the elements on which life subordinately depends. These last are almost the only unsymmetrical relations.

A remarkable result is reached (in figures not reproduced here) by placing the elements on the helix in their true positions as determined by the real differences between successive elements rather than by the average differences for each type of circle. It is found that the agreement with the ideal position is much less perfect than might have been expected, and curious and unexpected symmetries come to light. It is further found that

the elements can be nearly as well placed on the curve by using the successive differences

other, many elements in the first being as much too advanced as those in the other are

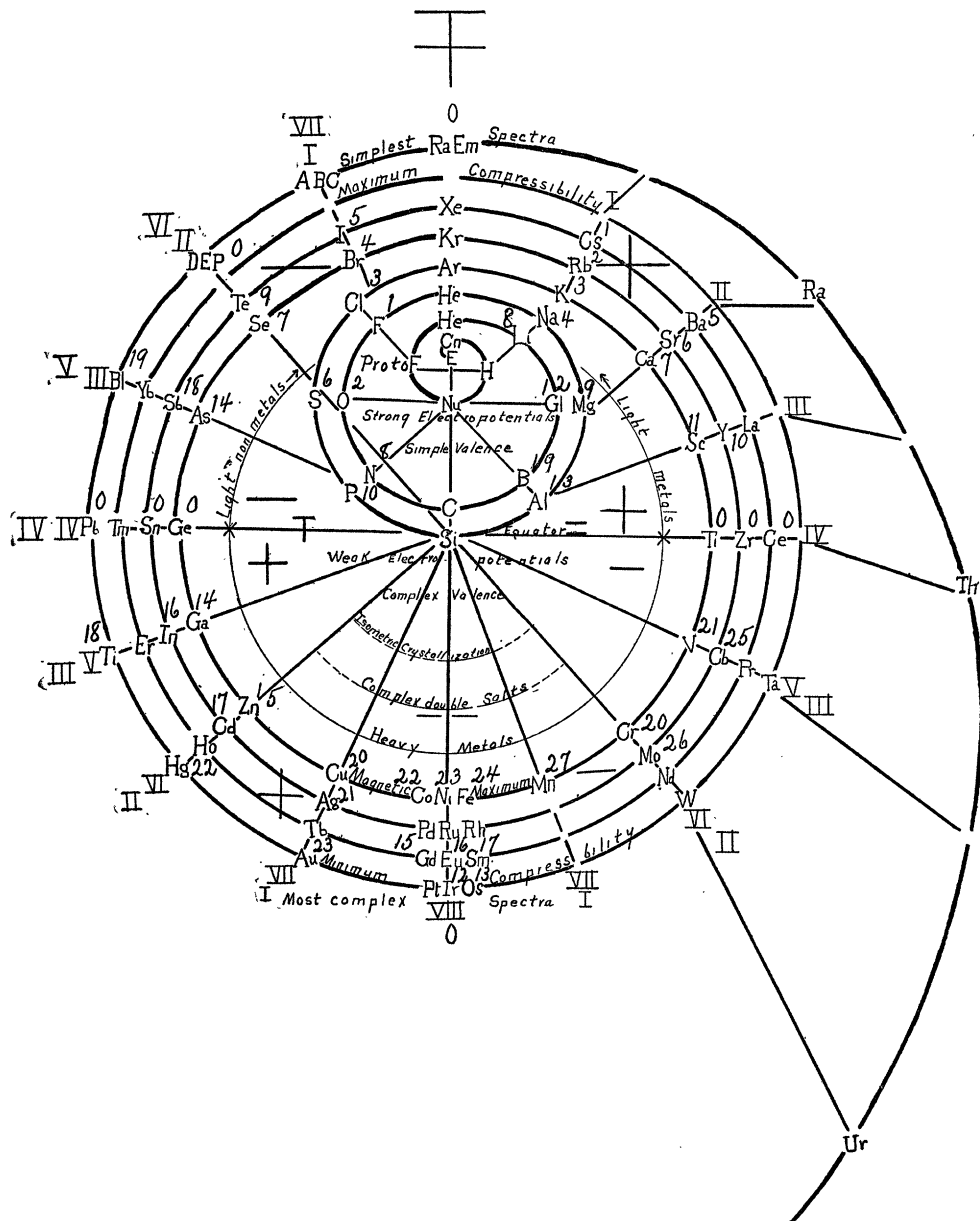


FIG. 4. Equatorial and Quadrantal Relations. Values of the electropotentials of the elements in detail. The printed numbers represent the order of these values, beginning with the highest. All the horizontal expressions refer to all the elements of the hemisphere in which they are placed.

of the densities, and that the inequalities of the two curves largely counterbalance each

retarded. So that a table made by taking the average position indicated by the atomic

weight and the density differences brings the elements much nearer the true position. It is then inferred that the distance on the last curve by which each element is separated from its ideal position, taken with opposite sign,

This brings into clear light the relative importance of valence, atomic weight, density and the ideal "position." The atomic weights have had a primary value in placing the elements nearly in that natural order,

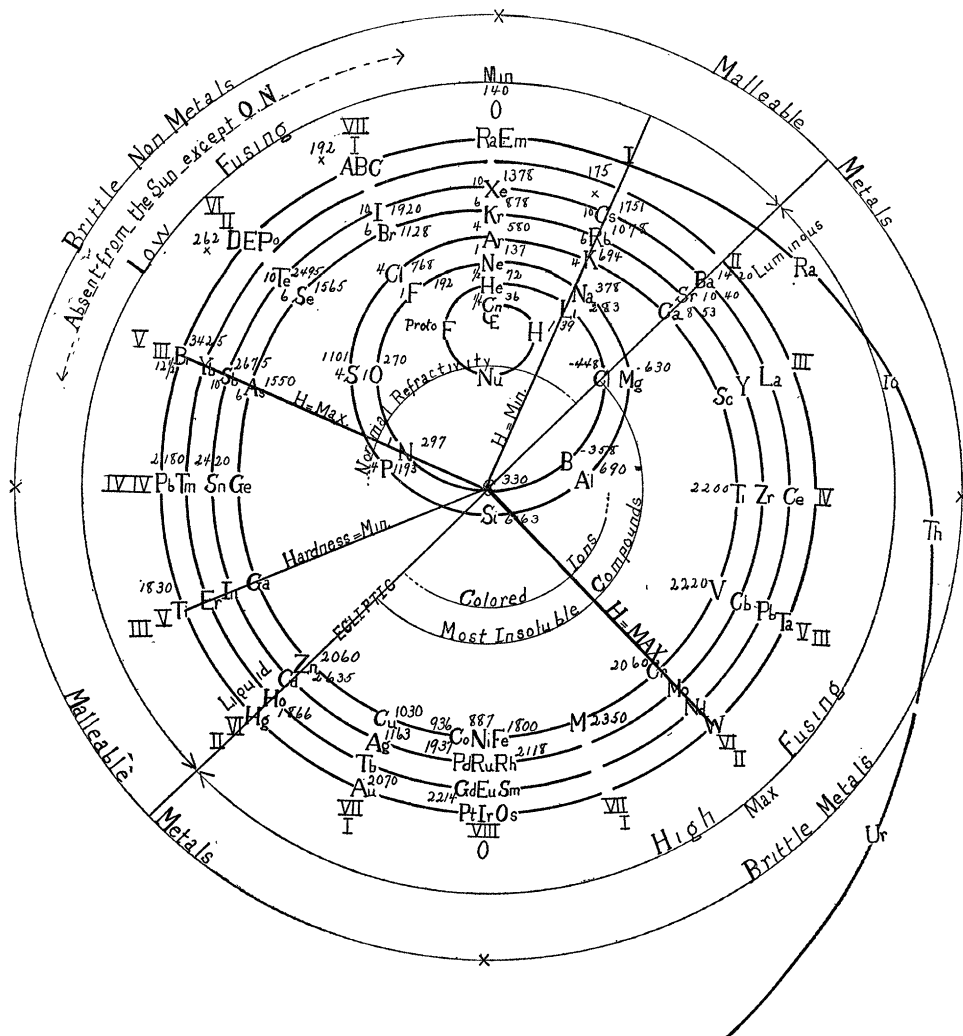


FIG. 5. Ecliptic Relations. Refractivity in detail. The large number on the right is the coefficient of refractivity. The small one on the left represents the factor to be multiplied into the constant at the border to obtain this refractivity.

would represent the value of the remaining functions which influence the position of the elements. We must perhaps go back to the conditions of formation of the elements to find these values reduced to zero.

which has brought out their periodic or harmonic relations, and the suggestion of a "position" of ideal symmetry. It had something the value of a scaffolding to the completed building.

3. *Evolution and Devolution*

The helix is a working model and it suggests that there is only one enduring stable

As the vix-generatrix passed over each unit space in the first circle the conditions favored the formation of a new element. In this cir-

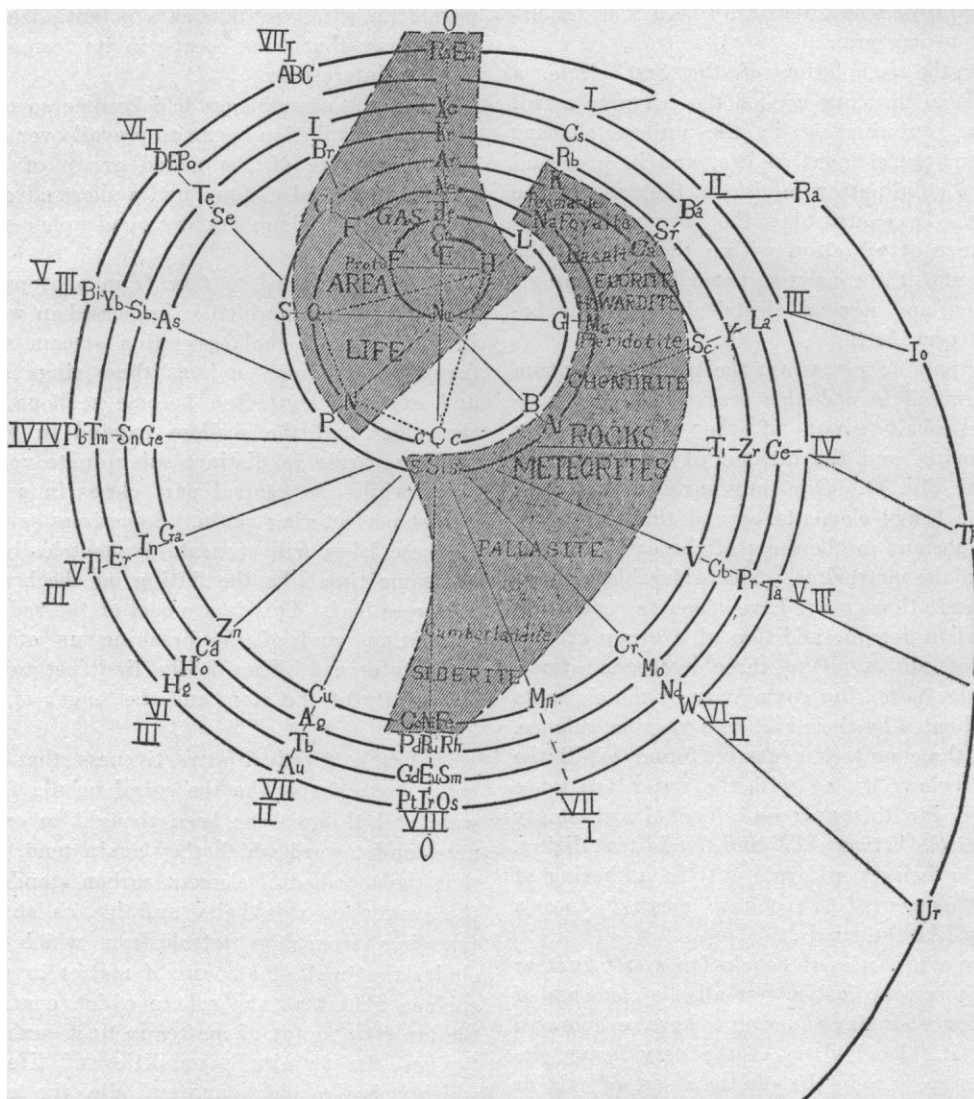


FIG. 6. Allied relations of partial or complex symmetry which do not come into the preceding categories. They are described in the section with which they are most nearly related.

assemblage of corpuscles between das Urstoff and hydrogen with its thousand corpuscles, and if that element be coronium, it has endured only under the exceptional conditions of the corona.

cle are the simplest forms of matter from hydrogen to helium. They appear abundantly in the nebulæ; existing and perhaps formed, near the absolute zero, where no heat vibrations could yet be predicated and where unex-

plained electrical activities could cause the light of the nebulae. The helix prophesies the discovery of only one new element of low atomic weight, proto fluorine, and an intensified fluorine would naturally be a difficult element to capture.

On the completion of the first circle, a double momentum swelled the curve to a full octave, culminating in the unique element carbon, the element of life, and in a second octave culminating in silicon, the basis of the rocks. In contrast to the corpuscular temperature or vibration within the atom in the elements of the nebulae, normal molecular vibration and normal electrical conditions became prevalent.

On passing potassium the treble momentum culminated in a double octave with the iron-nickel-cobalt group of the hot stars, the meteorites and the interior of the earth (see top of Fig. 1). One may surmise that most of the heavy elements beyond this group are unimportant in the mass of the earth as they are in the meteorites. A considerable molecular radiation may have been a condition precedent for the addition of a group of corpuscles equivalent to three hydrogen atoms, and the increasing complexity of the elements is indicated by their high and varying valence. Will three new elements be found to fill the gaps below Mn or will the outer triads be robbed for this purpose. The almost empty semicircle between *Yb* and *Ta* is tantalizing, but the helix would rule out the gathering of the "elements of the rare earths" into a group like the triads.

The sun carries the evolution a step further and it is conceivable that all the elements of the lowest-fusing quadrant have evaporated from it. Lead alone of the very heavy elements appears in the sun as a sort of calx or caput mortuum, suggesting that evaporation into helium has reached its limit there. It is remarkable that at the farthest place from this volatile quadrant, at the outermost curve of the high-fusing semi-circle, the radium elements should be evaporating with explosive heat and light-giving violence over all the surface of the earth: should exist in the outer

layers of the earth only, and should be brought up by the light and highly acid pegmatite, whose quartz grains have been formed below 800°.⁴ Becker's suggestion of the genesis of pegmatite with uranium as a potentializer of the energy that must escape in its formation is most interesting.⁵

When the assemblages had become so complex that devolution began to prevail over evolution the size of the added group of corpuscles increased to four, and a short advance only was made along the first quadruple-octave ring.

If ink is allowed to flow from a dropping tube, the point of which is immersed in water in a tall glass, the descending stream soon forms vortex rings and, as these rings sink and expand, they often become scalloped at the edges and the scallops expand in lobes which separate in distinct subordinate vortex rings while the central part closes in as an almost perfect ring again. Sometimes several of these lobes will separate symmetrically at the same time like the fluting on the border of a rose leaf. This is a model of the radium emanations and of the breaking up of the complex atoms. Thus is the limit set to the complexity of the atom and the length of the helix.

It has a mystical attractiveness that the helix has a shape like the spiral nebula from which all things have been thought to originate, and toward which they again tend, and that the tetrahedral element carbon stands in the center of this helix and by its shapes (ranging from the tetrahedron which includes the smallest amount of matter in unit surface almost to the sphere which contains the largest amount of matter in unit surface) typifies the infinite possibilities of life of which it is the vehicle and embodies the tetrahedral form which the earth has repeatedly if imperfectly assumed.⁶ B. K. EMERSON

⁴ Day and Shepard, *Am. Jour. Sc.*, Vol. XX., p. 276, 1906.

⁵ G. F. Becker, "Radioactivity and Cosmogony," *Bull. Geo. Soc.*, Vol. 19, p. 143.

⁶ T. Arldt, "Die Entwicklung der Erde," p. 506, 1907.